Saskatchewan
Agriculture
and Food

FINAL REPORT

BEEF DEVELOPMENT FUND

20020240

EVALUATION OF THE NRC 1996 FEED REQUIREMENTS FOR WINTERING BEEF COWS - ARE WE OVER FEEDING OUR COWS/PHASE 2 LACOMBE ALBERTA

Funded by
The Beef Development Fund

March, 2007

Prepared by: University of Saskatchewan

Evaluation of the NRC 1996, Feed Requirements for Wintering Beef Cows

"Are We Over-Feeding our Cows" ?

Phase 2 Lacombe Alberta

SBDF Project # 20020240

Final Report

February 2007

This is a combined summary of the research work done at Agriculture Canada Lacombe Research Centre and Dept of Animal Science University of Saskatchewan under SBDF project #20020020 and the project at Lacombe Alberta #20020240

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Executive Summary:

The objects of the project were to:

1. compare actual dry matter intake and weight gains of wintering beef cows to that predicted by the NRC 1996 model.

2. determine the winter feed requirements of cows in good body condition when fed under a variety of western Canadian feeding conditions at Saskatoon, Melfort and Lacombe

3. use the results to make recommendations to nutritionists and livestock agrologists to refine the computer prediction software such as ""Cowbytes" for formulating diets for beef producers.

In order to achieve these objectives, 3 years (2002/03, 2003/04, and 2004/05) of data on 90 black Angus cows (average weight 1275 lbs) fed in 15 pens of 6 cows each at the Western Beef Development Centre's herd at Lanigan, Saskatchewan were collected. An additional 5 years (1981/82, 1982/83, 1983/84, 1984/85, and 1985/86) of winter feeding data were compiled from early vs. late calving trials conduct at Melfort, Saskatchewan using 240 crossbred cows (Angus × Hereford or Simmental × Hereford) fed in 8 pens of 30 in each year. Data were also collected from 3 years (2003/04, 2004/05, and 2005/06) of net feed efficiency trials in Lacombe, Alberta which each used 40 crossbred (Angus × Hereford or Charolais × Maine Anjou) cows with individual intake records.

For all trials, cows were individually weighed at the beginning, end, and periodically during the winter period. Cows were condition scored throughout the trials, and only pregnant cows were included in the evaluation. Ultrasound was also used to measure body fat stores for all cows. Essential data collected included pen DMI (individual cow DMI for Lacombe), individual cow weights, body condition scores, calving dates and weights, and daily temperature and wind speed. Diet energy density was estimated from nutrient analysis of feed samples. With the Lanigan trials, the winter feeding program was broken up into two periods to permit more targeted feeding management. These periods ran from November through beginning of 3rd trimester and from the 3rd trimester through calving. Formulated diets for all trials were intended to allow cows to maintain condition and gain only that weight associated with developing pregnancy while consuming feed *ad libitum*. Diets for all trials were barley silage and cereal straw based with additional grain, hay and protein, mineral, and vitamin supplements being provided as needed. This resulted in wintering diets containing on average ~50 to 55% TDN, and 7-8% or more CP. Additionally, during the spring/summer of the first two years of the Lanigan trials, a digestibility trial was carried out in the metabolism barn of the Department of Animal and Poultry Science in order to determine digestible energy content of the wintering rations.

In terms of our primary objective of determining the accuracy and precision of the "NRC" model predictions of intake and gain and the relationship these have to the winter feed requirements of pregnant beef cows in western Canada the following comparisons were made:

1. Observed vs. predicted dry matter intake of cows, and
2. Observed vs. predicted body weight gains.

Evaluations compared observed and predicted DMI and conceptus corrected ADG for all trials using regression, means comparison, concordance correlation coefficient (CCC), and 90% total deviation index (TDI_{90}) methods. Across all trials, DMI was accurately predicted (P=0.12), but with low agreement between observed and predicted intake (CCC = 0.42) and such poor precision (TDI_{90} = 3.32 kg/d) using actual environmental conditions that these predictions would have limited practical applicability. Assuming thermal neutral conditions decreased the prediction of DMI resulting in an under prediction (P<0.01) of DMI with lower agreement and precision (CCC = 0.27, TDI_{90} = 4.00 kg/d). Across all the trials, ADG was largely under predicted (P<0.01) with low precision (CCC = 0.10, TDI_{90} = 1.07 kg) using actual environmental conditions, but over predicted (P<0.01) with similar precision (CCC = 0.14, TDI_{90} = 0.83 kg) when assuming TN conditions. These results indicate a lack of accuracy and precision with the current NRC (1996, 2000) model energy requirement equations and a lack of precision with the DMI equations that was not addressable by assuming TN conditions and would limit practical application of these predictions. Future research should be targeted at alternate DMI equations with greater precision and refinements to maintenance and gain requirement equations.

In summary, this evaluation of NRC (1996, 2000) model energy requirement and DMI equation for wintering beef cows in western Canada found the equations to lack accuracy and precision in prediction of intake and gain. This situation was not resolved by removing the impact of the environment based adjusters by assuming thermal neutral conditions and calls into question the practical applicability of the equations for use in beef cow feeding management. There are several possible areas where improvements could be made in the predictions of intake and gain of beef cows. These include development of equations that are more reflective of the limitations to DMI by cows (i.e. fill effects instead of chemo-osmotic effects); maintenance energy requirement equations that are specific to cows instead of using equations adapted from feedlot cattle, and gain prediction equations that reflect that the composition of gain changes with cow condition. These are all issues that have not been addressed in the current energy requirement and intake equations. The inability of the current equations to accurately and precisely predict intake and gain of wintering beef cows should not be viewed as a failure, but rather a success in providing direction for future research. Many of the issues discussed as limitations to the model equations exist only because there is a lack of quality data available for resolving them.

Methodology and Results: The following is a complete presentation of materials and methods, and results in a form that will be submitted to the Journal of Animal Science for publication purposes.

An additional research paper will be submitted to Canadian Journal of Animal Science summarizing the research findings of the entire data set including the Melfort, Lacombe and Saskatoon cows. This will be done after the initial paper dealing mainly with the methodology and specific University of Saskatchewan / Western Beef Dev. Centre cows has been accepted.

Title: A further evaluation of NRC (1996, 2000) model energy requirement and DMI equation accuracy and precision for wintering beef cows in western Canada.

Abstract

Three sets of winter feeding trial data were used to evaluate the accuracy and precision of NRC (1996) energy requirement and DMI equations. The first data set was three years of NRC (1996, 2000) model evaluation trials from the University of Saskatchewan, each using 90 Angus cows (15 pens of six). The second data set was three years of net feed efficiency trials from the Lacombe Research Center, each using 40 Angus × Hereford or Charolais × Maine Anjou cows (individual DMI). The third data set was five years of early vs. late calving trials, each using 240 Angus × Hereford or Simmental × Hereford cows (eight pens of 30). All cattle were fed typical wintering diets. Data collection included DMI, cow weights, body condition scores, calving dates and weights, and daily temperature and wind speed. Diet energy density was estimated from nutrient analysis of feed samples. Equation evaluations compared observed and predicted DMI and conceptus corrected ADG using regression, means comparison, concordance

correlation coefficient (CCC), and 90% total deviation index (TDI_{90}) methods. When all of the data sets were used in a collective evaluation, DMI predictions made using actual environmental conditions were accurate (P=0.12), but showed low agreement between observed and predicted DMI (CCC = 0.42) and poor precision (TDI_{90} = 3.32 kg d^{-1}). Removing the temperature based adjustment to DMI prediction by assuming thermal neutral (TN) conditions resulted in a general under prediction (P<0.01) of DMI with lower agreement (CCC = 0.27) and precision (TDI_{90} = 4.00 kg d^{-1}). Cow ADG was largely under predicted (P<0.01) with low agreement between observed and predicted ADG (CCC = 0.10) and low precision (TDI_{90} = 1.07 kg) using actual environmental conditions, but was generally over predicted (P<0.01) with similar agreement and precision (CCC = 0.14, TDI_{90} = 0.83 kg) when assuming TN conditions. These results indicate a lack of accuracy and precision with the current NRC (1996) model energy requirement equations and a lack of precision with the DMI equations that was not addressable by assuming TN conditions and would limit practical application of these predictions. Future research should be targeted at alternate DMI equations with greater precision and refinements to maintenance and gain requirement equations.

Introduction

Previous evaluations of the National Research Council (NRC; 1996, 2000) beef model (Block et al. 2001, 2006) have found the model to lack accuracy, but have been focused on evaluation of feedlot cattle performance. Evaluations of model intake and gain predictions for wintering beef cows are not readily available. The objective of this project is to evaluate the NRC (1996, 2000) beef model with regard to its ability to predict the feed intake and weight change of Canadian beef cows during the winter feeding period, and if necessary once the model

evaluation is complete, to provide suggestions for refining the model equations to more accurately predict feed intake and weight changes.

To more readily facilitate this objective, the model equations from the NRC beef model (1996, 2000) that specifically applied to non-lactating, pregnant cows were entered into a MS Excel spreadsheet. Use of this format has the distinct advantage of allowing more rapid modeling of large data sets, and will also allow modifications to be made to the equations used during the refinement phase of the project. Additionally, this format allows the evaluation to focus more specifically on the animal side of the NRC (1996, 2000) equations. Given the frequently limited nature of diet analysis available from historical data sets, including most of the ones available for these evaluations, the Level 2 approach to nutrient supply modeling which is based on the Cornell Net Carbohydrate and Protein System (CNCPS; Fox et al. 1992; O'Connor et al. 1993; Pitt et al. 1996; Russell et al. 1992; Sniffen et al. 1992) was not included. The nutrient supply modeling is more comparable to the Level 1 approach where the user specifies an energy density for the diet, and optionally a crude protein (CP) and degradable/undegradable intake protein (DIP/UIP) balance. Energy is entered either on the basis of total digestible nutrients (TDN), digestible, metabolizable, or net energy (DE, ME, NE). The CP values are optional as the NRC (1996, 2000) equations are focused on energy first and protein second. Failure to enter CP values merely limits evaluation to the accuracy of energy modeling and the assumption that the cattle have received adequate protein. Additionally, there is the option to predict energy content of the feed based on acid detergent fibre (ADF) content and Penn State equations from the National Forage Testing Association (NFTA 1993). A separate MS Excel spreadsheet was set up with additional feed energy content prediction equations (Goering and Van Soest 1970; Weiss et al. 1992) for use when more detailed feed analysis data are available.

Materials and Methods

Saskatoon Data Sets

The Saskatoon data sets are from 2002-2003, 2003-2004, and 2004-2005 winter feeding trials conducted at the Termuende Research Farm near Lanigan, SK by researchers at the University of Saskatchewan. Each of these winter feeding trials began with 15 pens of 6 of mature commercial Angus cows. All cows were pregnancy checked at the beginning of the trial which allowed the cows to be managed in early, mid, and late calving groups and to divide the winter feeding period in to two evaluation periods. The first period roughly corresponded to the 2nd trimester and began November 5 for the 2002-2003 winter feeding trial, November 4 for the 2003-2004 winter feeding trial, and November 9 for the 2004-2005 winter feeding trial and ended approximately eight weeks before calving. The second period roughly corresponded to the 3rd trimester and began approximately 8 weeks before calving and ended approximately 2 weeks before calving. Trial and 3rd trimester evaluation period end dates varied with pen and year but ranged from March 23 to May 5.

The first two years of these data were used for a M.Sc. project by J. Bourne evaluating the accuracy of the CowBytes software program from Alberta Agriculture, which was based on the NRC (1996, 2000) model equations. For the current project, all three years of data have been used in evaluating the accuracy of intake and gain predictions made by the specific subset energy based equations of NRC (1996, 2000) appropriate for mature cows. Evaluations were carried out separately for each of the two periods, both individually and collectively for the three trials.

All cattle were housed in outdoor 7.4 m by 24.5 m pens with a feed bunk running along the short southern edge of the pens, and a 20% porosity windbreak 2.4 m beyond the northern edge of the pens. Cattle were bedded twice weekly with woodchips and provided additional

straw bedding for comfort to offset inclement conditions when deemed appropriate by the herdsperson.

Cattle were fed total mixed rations formulated to meet their nutrient requirements (NRC 1996, 2000) once daily. *Ad libitum* intake should have resulted in zero weight gain beyond that associated with fetal growth and feed supplied was 5 to 10% in excess of this amount. Feed bunks were cleaned weekly to track feed refusals. An early gestation ration based on barley green feed and oat straw, and a late gestation ration based on alfalfa hay, barley grain, and oat straw were used, and cattle had *ad libitum* access to mineral supplements. Nutrient content of were used to estimate diet TDN according to Weiss et al. (1992). Transition between use of early and late gestation rations did not match the transition between 2nd and 3rd trimester evaluation periods.

Lacombe Data Sets

The Lacombe data sets are from 2003-2004, 2004-2005, and 2005-2006 winter feeding trials conducted at the Lacombe Research Center at Lacombe, AB. Each trial was evaluating the net feed efficiency of 40 Angus × Hereford or Charolais × Maine Anjou. The period of useable data from the 2003-2004 winter feeding trial ran from December 9, 2003 to February 4, 2004. The portion of the winter feeding data from the 2004-2005 and 2005-2006 winter feeding trials that was suitable for use in this evaluation was longer, running from October 30, 2004 to February 16, 2005 and from October 28, 2005 to February 15, 2006, respectively.

Cows were confined in feedlot pens equipped with Grow-Safe feeders which allowed tracking of individual animal intakes and modeling of individual animal performance. The ration fed consisted of a barley silage/barley straw blend (40:60 DM basis) with the addition of a small

amount of 32-12 protein supplement. Obtaining reasonable estimates of the diet energy values for the 2003-2004 and 2004-2005 winter feeding trials diets was a definite challenge. The commercial laboratory feed analysis generated acid and neutral detergent fibre values (ADF, NDF) that were lower than expected for barley silage or barley straw and analysis of repeat samples indicated low repeatability. The lower than expected fibre values meant that use of Weiss et al. (1993), Goering and Van Soest (1967) or Pennsylvania State (Adams, NFTA) equations to estimate TDN values resulted in values that were markedly higher than expected TDN contents for these feeds. Eventually, feed analyses were run in-house at Lacombe which gave much more reasonable energy values (using Pennsylvania State equations for corn silage and grass for barley silage and barley straw, respectfully) which were used to determine diet energy content. For the 2005-2006 winter feeding trial, the Pennsylvania State equation for grass was again used to estimate the TDN content of barley straw, although the Weiss et al. (1993) forage equation was found to generate the most reasonable value for the barley silage.

Melfort Data Set

The Melfort data set consists of historical feeding data from trials conducted at Melfort from 1981-1985 with each year of winter feeding using 240 Angus × Hereford or Simmental × Hereford cows fed in eight pens of 30. Not all of this data was suitable for use in evaluating the NRC (1996, 2000) model equations as applicable to feeding of non-lactating pregnant cows. Failure of suitability was usually due to a mismatch of feed intake and animal weight data, or periods of data that covered pens of cows that were calving. When data were filtered, 40 pen periods of data with 30 cows per pen were available for evaluation. Useable evaluation periods ran from October 29, 1981 to January 22, 1982, November 3, 1982 to January 16, 1983, October

21, 1983 to January 23 or 24, 1984, October 30, 1984 to January 8 or 9, 1985, and October 31, 1985 to January 6, 1986.

Cows in the Melfort data set were involved in an early vs. late calving date trial. Cows were housed in outdoor pens and were fed diets based on barley silage, cereal straw, and barley grain. The TDN content of the diets fed to the Melfort data set cows was determined from diet composition data and a combination of feed analysis based estimates and reference TDN values.

Other Data Sets

Additional data from historical trials conducted at Brandon, MB, at Nappan, NS, and Onefour, AB (Bowden 1980) were intended for inclusion in this evaluation, but were found to be unsuitable for use in evaluating the energy requirement and DMI equations for gestating, non-lactating wintering beef cows. Reasons for unsuitability included absent or missing data, or to a requirement for extensive data screening and processing without the assurance of usable information when completed. These data sets were subsequently dropped from this evaluation although they may yet have use in addressing specifically identified modelling issues.

Data Collection and Calculations

Cows in all included trials were weighed individually before feeding at the beginning and end of the trial, and periodically during the course of the trial. Cow weights were adjusted for conceptus weight according to NRC (2000) before determining ADG or shrunk body weights for model inputs using the following equation:

CW, kg

$$= 0.01828 \text{ CBW} \times e^{(0.02 \times t - 0.0000143 \times t^2)}$$

Where:

CW is conceptus weight in kg,

CBW is calf birth weight in kg, and

t is days pregnant.

It is important to note that the NRC (1996) equation has a decimal place shift that results in unrealistic conceptus weights.

Equations used for evaluation were all from NRC (1996, 2000) and are represented for clarity. The first set of calculations involved conversion of dietary TDN values to NE_m values:

DE, Mcal kg^{-1}

$= 4.409 \text{ TDN}$

ME, Mcal kg^{-1}

$= 0.82 \text{ DE}$

NE_m, Mcal kg^{-1}

$= 1.37 \text{ ME} - 0.138 \text{ ME}^2 + 0.0105 \text{ ME}^3 - 1.12$

Where:

DE is digestible energy in Mcal kg^{-1},

ME is metabolizable energy in Mcal kg^{-1}, and

NE_m is net energy for maintenance in Mcal kg^{-1}.

After calculation of NE_m, intake was estimated for non-lactating pregnant cows in their last two thirds of pregnancy.

DMI, kg d^{-1}

$$= SBW^{0.75} ((0.04997\ NE_{ma}^{2} + 0.04361) \div NE_{ma}) \times TEMP \times MUD$$

Where:

SBW is shrunk body weight in kg after correction for conceptus,

NE_{ma} is net energy for maintenance available from the diet in Mcal kg^{-1},

TEMP is an adjustment based on temperature where intake is increased by 16% when temperature is below -5 °C, increased by 5% when temperature is between -5 and 5 °C, increased by 3% when temperature is between 5 and 15 °C, or decreased by 10% when temperature is above 25 °C, and

MUD is an adjustment based on mud depth where intake is decreased by 15% when mud depth is between 10 and 20 cm or decreased by 30% when mud depth is between 30 and 60 cm.

The calculation of intake was subject to the limitation that if diet NE_{ma} is <1.00 Mcal kg^{-1}, then diet NE_{ma} is set at 0.95 Mcal kg^{-1}. Intake estimation was followed by estimation of NE_m requirements without accounting for any possible acute cold stress effects.

NE_m, Mcal d^{-1}

$$= (0.077 + 0.0007\ (20 - T_p))\ SBW^{0.75}\ (0.8 + ((CS - 1) \times 0.05)$$

Where:

T_p is an acclimation adjustment to NE_m requirements based on previous temperature in °C,

SBW is shrunk body weight in kg after correction for conceptus, and

CS is an adjustment based on body condition score (9-point scale).

This initial NE_m requirement is then used to estimate the lower critical temperature of the cattle and determining if additional energy will be required to offset acute cold stress. These calculations also require estimation of the NE_m required for pregnancy.

NE_{preg}, Mcal d^{-1}

$$= CBW \times (k_m \div 0.13) \times (0.05855 - 0.0000996 \times t) \times e^{((0.03233 - 0.0000275 \times t) \times t)} \div 1000$$

Where:

CBW is calf birth weight in kg,

k_m is diet $NE_m \div$ diet ME, and

t is the day of pregnancy.

Lower critical temperature estimation is based on a comparison of cattle surface area and normal heat production relative to cattle external and tissue insulation. First is the calculation of surface area.

SA, m^2

$$= 0.09\ SBW^{0.75}$$

Where:

SBW is shrunk body weight in kg after correction for conceptus.

Surface area calculations are followed by estimation of heat production.

HE, Mcal m^{-2} d^{-1}

$= (MEI - (NE_m + NE_{preg})) \div SA$

Where:

MEI is metabolizable energy intake in Mcal d^{-1},

NE_m is net energy requirement for maintenance before cold stress in Mcal d^{-1},

NE_{preg} is net energy requirement for pregnancy in Mcal d^{-1}, and

SA is surface area in m^2.

After heat production is estimated, then estimates are made of external insulation.

EI, °C $Mcal^{-1}$ m^2 d^1

$= (7.36 - 0.296\ WIND + 2.55\ HAIR) \times MUD \times HIDE$

Where:

WIND is wind speed in km h^{-1},

HAIR is effective hair depth in cm,

MUD is an adjustment factor for hide condition where external insulation is decreased by 20% if there is some mud on the lower body, decreased by 50% if the hide is wet and matted, and decreased by 80% if the hide is covered with wet snow or mud, and

HIDE is an adjustment factor where external insulation is increased by 20% if the cattle have Hereford breeding.

External insulation estimation is followed by tissue insulation estimation.

TI, °C $Mcal^{-1}$ m^2 d^1

$= 5.25 + (0.75 \times CS)$

Where:

CS is body condition score (9-point scale).

Lower critical temperature can then be estimated based on total insulation and heat production.

LCT, °C

$= 39 - (EI + TI) \times HE \times 0.85$

Where:

EI, is external insulation in °C $Mcal^{-1}$ m^2 d^1,

TI, is tissue insulation in °C $Mcal^{-1}$ m^2 d^1, and

HE is heat production in Mcal m^{-2} d^{-1}.

If the current temperature is lower than this estimated lower critical temperature, then it is necessary to estimate then NE_m required to offset acute cold stress.

NE_{mcs}, Mcal d^{-1}

$= k_m (SA (LCT - T_c) \div (EI + TI))$

Where:

k_m is diet $NE_m \div$ diet ME,

SA is surface area in m^2,

LCT is the lower critical temperature in °C,

T_c is the current temperature in °C,

EI, is external insulation in °C $Mcal^{-1}$ m^2 d^1, and

TI, is tissue insulation in °C $Mcal^{-1}$ m^2 d^1.

At this point, the NE_m requirements for maintenance without cold stress, pregnancy, and any effect of cold stress can be subtracted from total NE_m intake and weight gain or loss can be estimate based on any surpluses or deficiencies in energy intake.

ADG, kg d^{-1}

$= ((DMI \times NE_{ma}) - (NE_m + NE_{preg} + NE_{mcs})) \div 5.82$

Where:

DMI is DM intake in kg d^{-1},

NE_{ma} is net energy for maintenance available from the diet in Mcal kg^{-1},

NE_m is net energy requirement for maintenance before cold stress in Mcal d^{-1},

NE_{preg} is net energy requirement for pregnancy in Mcal d^{-1}, and

NE_{mcs} is net energy requirement for maintenance due to acute cold stress in Mcal d^{-1}.

In the case of a predicted deficient energy intake, the prediction of ADG needs to be modified to reflect the lower efficiency of mobilizing tissue reserves to meet NE requirements. This is done by dividing negative predictions of ADG by 0.8.

Model Inputs

While taken directly from the published NRC (1996, 2000) model prediction equations, it is important to note that the relatively narrow focus of this current study allowed many of the equations to be simplified. For example, with all of the cattle in these studies being non-lactating cows, lactation, and gender effect modifiers for estimation of NE_m requirements could be dropped. Additionally, by focusing only on the cattle energy requirement equations, the number of inputs required to generate predictions were also greatly reduced. Required dietary inputs consisted of information on DMI, TDN, and use of an ionophore. Both DMI and TDN data are summarized in Tables 1 and 2, and none of the diets fed contained an ionophore.

Required environmental information included existence of night cooling to offset heat stress, pen mud depth as a modifier on intake, previous and current temperature, wind speed, effective hair depth, and effect of hide condition and thickness on external and tissue insulation. With these winter feeding trials, night cooling to offset heat stress was not a factor in the model predictions. Likewise, generally frozen pen conditions removed pen mud depth as a modifier of intake. Previous temperatures are summarized in Tables 1 and 2 and were taken as the average temperature for a time period as long as evaluation periods, but starting 28 d earlier. Current temperatures and wind speed were the averages over the feeding periods and are also summarized in Tables 1 and 2. Wind speeds were reduced to on third of their original values to reflect the sheltering effects of windbreaks. Effective hair depth was set to the NRC (1996,

2000) model suggest default of 1.27 cm. Evaluations were also carried out assuming thermal neutral conditions by using previous and current temperatures of 20°C and a wind speed of 0 km/h.

Tissue insulation value determination changes with animal age up to 1 year after which cattle of all ages are dealt with similarly. With this study focusing on mature cows, exact animal age would not affect predictions of intake or gain. Details on shrunk body weights after adjusting for conceptus weight, body condition scores (9-point scale), days pregnant, and calf birth weight are all summarized in Tables 1 and 2. The shrunk body weight, body condition scores, and days pregnant all represent averages over the evaluation period. Observed ADG is also presented in Tables 1 and 2.

Statistical Analyses

Statistical analyses for evaluation of NRC (1996, 2000) model DMI and energy requirement equation accuracy and precision involved a variety of methods to ensure that any deficiencies identified with one method would be covered through application of another method.

Evaluation of accuracy began with regression of observed and predicted DMI or ADG. Statistics noted included intercept and slope estimates and standard errors, the coefficient of determination (R^2: proportion of variation in observed DMI or ADG explained by predicted DMI or ADG) and root mean square error ($s_{y,x}$: total deviation in observed DMI or ADG not explained by predicted DMI or ADG). Bias (absolute difference between means) was also noted and the mean square error of prediction was determined and partitioned into bias (difference between means), slope (difference from unity), and residual (random error or lack of correlation)

components as described by Rice and Cochran (1984). The test for accuracy with regression of observed and predicted intakes or gains involved a comparison between the fitted regression relationship and the isopleth (observed = predicted). Identification of a difference ($P<0.05$) between the fitted regression relationship and the isopleth indicates inaccurate prediction whereas failure to identify any difference ($P>0.05$) leads to acceptance of model accuracy. However, this test is only valid if there is a relationship ($P<0.05$) between observed and predicted DMI and ADG.

If there was no regression relationship ($P<0.05$), residuals (predicted – observed) were regressed on predicted DMI and ADG. Again, statistics noted included intercept and slope estimates and standard errors, the coefficient of determination (proportion of variation in residual DMI or ADG explained by predicted DMI or ADG) and root mean square error (total deviation in residual DMI or ADG not explained by predicted DMI or ADG). In this case, the existence ($P<0.05$) of any regression relationship indicates inaccurate prediction. However, failure ($P>0.05$) to identify a relationship between residuals and predicted DMI and ADG is considered inconclusive and does not ensure accuracy.

In the event that regression of both observed and residual DMI and ADG on predictions were inconclusive, means comparison of observed and predicted DMI or ADG was the final evaluation of accuracy. Predicted values were designated as the independent variable for all regression analyses as there is no experimental uncertainty associated with predicted DMI or ADG once model inputs are specified.

Evaluation of precision also involved several different methods including the concordance correlation coefficient (CCC), the 90% total deviation index (TDI_{90}), and coverage probability (CP) tests as described by Lin (1992, 2000) and Lin et al. (2002). The CCC is the

product of accuracy (correlation between regression estimates and model predicted DMI or ADG) and precision (correlation between observed and predicted ADG or DMI) correlation coefficients. A CCC value of 1 indicates perfect agreement, 0 indicates no agreement, and -1 indicates perfect disagreement between observed and predicted DMI or ADG. The TDI_{90} represents absolute difference between individual pen observed and predicted DMI or ADG for which 90% of the pens would have a lower value. The TDI_{90} statistic contrasts with the CP statistic which is the proportion of data where the difference between observed and predicted values falls within a pre-specified absolute difference. For these evaluations, selected CP limits were 1.0 kg d^{-1} for DMI and 0.25 kg for ADG. To protect against type II errors, both the TDI_{90} and CP statistics are considered appropriate only if the relative bias square statistic is ≤ 1.

All analyses except the mean square error partitioning were carried out using SAS (SAS Institute Inc., Cary NC) regression or mixed models procedures or a macro provided by L. Lin (Baxter Health Care Corp., Round Lake, IL). The mean square error partitioning was done manually.

Results and Discussion

Accuracy and Precision of DMI Predictions

Figure 1 is a plot of observed vs. predicted DMI under actual environmental conditions for all of the data sets. Perfectly accurate prediction would occur if all plotted data points fell on the isopleth (solid line). Deviation from this would represent a lack of precision only as long as the fitted regression equation (dashed line) remained equal to the isopleth. Deviation between the fitted regression equation and the isopleth represents a lack of accuracy. Model evaluation

statistics shown relate to the combined analysis of all of the data sets using regression of observed vs. predicted DMI.

When the DMI data for the 2nd trimester of all three years of the Saskatoon data sets were evaluated collectively (Table 3), predicted DMI explained 69% of the variation in observed DMI with a $s_{y\,x}$ of 0.68 kg/d. However, these predictions were inaccurate ($P<0.01$) with a general over prediction of DMI and 74% of the inaccuracy due to bias, 10% due to slope, and 16% due to residual sources. The agreement between observed and predicted DMI was weak with a CCC of 0.24 while the relative bias square of 2.83 exceeded 1 and invalidated the TDI_{90} and CP statistics.

With the collective evaluation of the 3rd trimester of all three years of the Saskatoon DMI data (Table 3), there was no relationship ($P=0.12$) between observed and predicted DMI with predicted DMI explaining only 5% of the variation in observed DMI with a $s_{y\,x}$ of 0.80 kg/d. There was also no relationship ($P=0.21$) between residual and predicted DMI. Means comparison found DMI to be over predicted ($P<0.01$) by 4%. The CCC of 0.12 suggests no relationship between observed and predicted DMI, and the relatively large TDI_{90} of 1.57 kg/d, and the fact that <70% of the pens of cows evaluated would be expected to have observed and predicted DMI agreeing within 1 kg/d limits the practical applicability of the DMI predictions.

Combining all of the Lacombe DMI data for evaluation (Table 4) revealed that there was a relationship ($P<0.01$) between observed and predicted DMI that explained 21% of the variation in observed DMI with a $s_{y\,x}$ of 2.34 kg/d. This relationship differed ($P<0.01$) from the isopleth indicating inaccurate prediction of DMI with 9% of the inaccuracy due to bias and 91% due residual sources of error. Intake was generally under predicted with the CCC of 0.33 indicating

low agreement between observed and predicted DMI. Low agreement was further supported by the large TDI_{90} of 4.03 kg/d and the 31% CP.

There was no relationship (P=0.91) between observed and predicted DMI with the Melfort data set (Table 4). Predicted DMI explained <1% of the variation in observed DMI with a $s_{y \cdot x}$ of 1.07 kg/d. There was a relationship (P<0.01) between residual and predicted DMI indicating inaccurate prediction of DMI. Intake was generally over predicted with the CCC of 0.01 indicating no agreement between observed and predicted DMI. Low agreement was further supported by the large TDI_{90} of 3.15 kg/d and the 37% CP.

When all of the data sets were combined for evaluation of DMI prediction accuracy and precision using actual environmental conditions (Table 4), there was a relationship (P<0.01) between observed and predicted DMI with predicted DMI explaining 24% of the variation in observed DMI with a $s_{y \cdot x}$ of 2.01 kg/d. This relationship did not differ (P=0.12) from the isopleth allowing the conclusion of accurate DMI prediction. Of the inaccuracy that did exist, 1% was attributed to bias, 1% to slope, and 98% to residual error. Despite the conclusion of accurate DMI prediction, precision was poor as indicated by the large TDI_{90} of 3.32 kg/d and the observation that only 38% of the individual cows or pens of cows evaluated would have had observed and predicted DMI agree within 1 kg/d.

One possible cause for the over prediction of DMI observed for the Saskatoon and Melfort data sets is that predicted DMI is increased with colder environments. The average current temperatures that cattle were exposed to would have result in a 16% increase in predicted DMI for all of the winter feeding trials except the 3rd trimester evaluation period of the 2004-2005 Saskatoon winter feeding trial and the 2005-2006 Lacombe winter feeding trial where there would have been a 5% increase in predicted DMI due to temperature. Re-evaluating the DMI

predictions under the assumption of thermal neutral conditions removes the effect of this adjuster and may result in more accurate and precise estimates of DMI by wintering beef cows.

When DMI data from 2nd trimester of all three years of the Saskatoon data set were evaluated collectively with the assumption of thermal neutral conditions (Table 5), there was a relationship (P=0.02) between observed and predicted DMI with predicted DMI explaining 12% of the variation in observed DMI with a $s_{y\,x}$ of 1.14 kg/d. This regression relationship did not differ (P=0.34) from the isopleth allowing the conclusion of accurate prediction. Of the inaccuracy that did exist, 58% was due to bias, 1% due to slope, and 41% due to residual sources. However, the CCC of 0.25 suggests agreement between observed and predicted DMI remained low, which was supported by the large TDI_{90} of 1.91 kg/d and the observation that only 60% of the pens of cows would be expected to have difference between observed and predicted DMI of less than 1 kg/d.

With the DMI data for the 3rd trimester of all three years of the Saskatoon data set evaluated collectively under the assumption of thermal neutral conditions (Table 5), there was no relationship (P=0.94) between observed and predicted DMI. Predicted DMI explained <1% of the variation in observed DMI with a $s_{y\,x}$ of 0.82 kg/d. There was a relationship (P<0.01) between residual and predicted DMI indicating inaccurate prediction of DMI. Intake was generally under predicted with predicted DMI being able to explain 43% of the variation in DMI prediction error.

For the Lacombe data sets where DMI had been under predicted when using the actual environmental conditions, reducing the prediction of DMI by assuming thermal neutral conditions and removing the temperature related adjuster would not be expected to improve the accuracy or precision of DMI prediction. This expectation was confirmed when the relationship

(P<0.01) between observed DMI and DMI predicted under the assumption of thermal neutral conditions (Table 6) was not equal (P<0.01) to the isopleth and accounted for only 9% of the variation in observed DMI with a $s_{y\,x}$ of 2.10 kg/d. The under prediction of DMI worsened with the assumption of thermal neutral conditions with 41% of the inaccuracy due to bias and 59% due to residual error. There was less agreement between observed and predicted DMI as indicated by a CCC of 0.11, a larger TDI_{90} of 5.39 kg/d, and a smaller CP of 22%.

When DMI was predicted assuming thermal neutral conditions, there was still no relationship (P=0.90) between observed and predicted DMI for the Melfort data set (Table 6). Predicted DMI explained <1% of the variation in observed DMI with a $s_{y\,x}$ of 1.07 kg/d. There was still a relationship (P<0.01) between residual and predicted DMI indicating inaccurate prediction, although DMI was now generally under predicted to a lesser degree than it had been over predicted when using actual environmental conditions. The CCC of 0.02 indicates no relationship between observed and predicted DMI while the TDI_{90} remained large at 2.26 kg/d with CP low at 52%.

When all data sets were combined and evaluated using actual environmental conditions, DMI predictions were found to be accurate but imprecise. Removing the temperature based adjustment to DMI predictions by assuming thermal neutral conditions under this situation would be expected to compromise the accuracy of the DMI predictions without necessarily improving precision. When all data sets were evaluated collectively under the assumption of thermal neutral conditions (Table 6), there was a relationship (P<0.01) between observed and predicted DMI that explained 18% of the variation in observed DMI with a $s_{y\,x}$ of 2.09 kg/d. However, this relationship differed (P<0.01) from the isopleth indicating inaccurate prediction of DMI with 26% of the inaccuracy due to bias, 1% due to slope, and 73% due to residual error. Intake was

generally under predicted with a CCC of 0.27 indicating low agreement between observed and predicted DMI. Precision was also low with a TDI_{90} of 4.00 kg/d and a CP of 31%.

Removing the temperature based adjustments to DMI predictions by assuming thermal neutral conditions did act against the over prediction of DMI observed when actual environmental conditions were used for the Saskatoon and Melfort data sets. However, this only resulted in improved predictions for the Melfort data set and the 2nd trimester evaluation period of the Saskatoon data sets. The Lacombe data sets and the 3rd trimester evaluation period of the Saskatoon data sets experienced worsened prediction of DMI, as did the combined analysis of all the data sets. Even when DMI was deemed to be predicted accurately, precision and agreement between observed and predicted DMI still limits the practical application of the NRC (1996, 2000) model predictions of DMI for wintering beef cows.

For those cases in which assuming thermal neutral conditions did improve prediction accuracy, it is important to note that this does not mean that these adjustments were responsible for the lack of accuracy and precision observed. The NRC (1996, 2000) model DMI prediction equation is based on SBW and diet energy density with diet energy values being set to fixed values with low energy diets. For many of the evaluated data sets, diet energy values were low enough that predicted DMI stops responding to changes in diet energy density and begin to be based on SBW only. While the NRC (1996, 2000) model DMI prediction equation does use diet energy density to reflect the scientific theory of that intake of high energy diets is limited by chemo-osmotic factors, there is no transition to any other form of prediction equation when diet energy density drops to the point where rumen fill or feed mastication time effects begin to be the DMI limiting factors. This observation suggest further research be directed to developing

intake prediction equations based on factors other than diet energy density, especially in the case of wintering beef cows where chemo-osmotic factors are not expected to limit feed intake.

Accuracy and Precision of ADG Predictions

Figure 2 is a plot of observed vs. predicted ADG under actual environmental conditions for all of the data sets. Model evaluation statistics presented relate to the evaluation of all the data using regression of observed vs. predicted ADG approaches. Both observed and predicted ADG reflect weight gain by cows in addition to the gains expected due to conceptus growth with advancing pregnancy.

When the 2nd trimester data of all three years of the Saskatoon data set were evaluated collectively (Table 7), there was a relationship ($P<0.01$) between observed and predicted ADG with predicted ADG explaining 69% of the variation in observed ADG with a $s_{y\,x}$ of 0.10 kg. However, this relationship differed ($P<0.01$) from the isopleth indicating inaccurate prediction of ADG. Of the inaccuracy observed, 42% was attributed to bias, 50% to slope, and 8% to residual error components. There was a general under prediction of ADG. The CCC of 0.50 suggest moderate agreement between observed and predicted ADG. However, the TDI_{90} of 0.58 kg and the observation that <50% of the individual cows or pens of cows would be expected to have observed and predicted ADG agree within 0.25 kg would limit practical application of these ADG predictions.

When all three years of 3rd trimester ADG data from the Saskatoon data sets were evaluated collectively (Table 7), there was no relationship ($P=0.18$) between predicted and observed ADG with predicted ADG explaining only 4% of the variation in observed ADG with a $s_{y\,x}$ of 0.17 kg. There was a relationship ($P<0.01$) between residual and predicted ADG

indicating inaccurate prediction. Predicted ADG was able to explain 49% of the variation in predicted ADG error. Observed and predicted ADG means were quite similar with ADG being under predicted with low predictions and over predicted with high predictions. The CCC of 0.20 indicates very weak relationship between observed and predicted ADG with the large TDI_{90} of 0.38 and CP of 70% indicating a lack of precision in ADG prediction.

Using actual environmental conditions for all of the Lacombe data sets (Table 8), there was a relationship (P=0.01) between observed and predicted ADG with 6% of the variation in observed ADG being explained by predicted ADG with a $s_{y\,x}$ of 0.22 kg. This relationship differed (P<0.01) from the isopleth indicating inaccurate prediction with 40% of the inaccuracy explained by bias, 52% slope, and 8% by residual error sources. Gain was generally under predicted. The low CCC of 0.10 indicates low agreement between observed and predicted ADG while the large TDI_{90} of 1.32 kg and low CP of 23% both indicate low precision.

With the Melfort ADG data (Table 8), there was no relationship (P=0.77) between observed and predicted ADG with <1% of the variation in observed ADG being explained by predicted ADG with a $s_{y\,x}$ of 0.23 kg. The relationship (P<0.01) between residual and predict ADG indicates inaccurate prediction with predicted ADG explaining 70% of the error in prediction. Gain was generally under predicted with little agreement between observed and predicted ADG (CCC = 0.01). The TDI_{90} of 1.21 kg was large, whereas the CP of 18% was low.

When all ADG data were combined (Table 8) for evaluation using actual environmental conditions, there was a relationship (P<0.01) between observed and predicted ADG with 4% of the variation in observed ADG being explained by the prediction with a $s_{y\,x}$ of 0.23 kg. This relationship differed (P<0.01) from the isopleth indicating inaccurate prediction of ADG with 33% of the inaccuracy due to bias, 54% due to slope, and 13% due to residual error components.

Gain was generally under predicted with a low CCC of 0.10 indicating little agreement between observed and predicted ADG. The large TDI_{90} of 1.07 kg and the observation that only 29% of the individual cows or pens of cows evaluated would be expected to have observed and predicted ADG agree within 0.25 kg would limit practical application of theses predictions.

There are several possible reasons why ADG would be under predicted for the wintering beef cows. Block et al. (2001) have suggested that with feedlot cattle the adjustments made to maintenance energy requirements in response to colder environmental conditions appear to be in excess of the thermal stress experienced by cattle and would to over estimation of maintenance energy requirements and subsequent under estimation of ADG. In their evaluations of feedlot cattle, Block et al. (2001) found that assuming thermal neutral conditions and removing the impact of environment on the maintenance energy requirements of steers did result in predictions of ADG that were closer to observed values. However, although the NRC (1996, 2000) model equations addressing the impact of environment on maintenance energy requirement do appear suspicious, the observations of Block et al. (2001) should not be taken as proof that this is a problem with ADG predictions, or that it is the only problem with ADG predictions.

The net energy system used by the NRC (1996, 2000) model is based on California feedlot steer data (Lofgreen and Garrett 1968; Garrett 1980) and the original base maintenance energy requirements were originally based on empty body weight. No adjustments were made to adjust the maintenance energy equations to use shrunk body weight, and there has apparently not been any evaluation specifically regarding the appropriateness of using maintenance energy equations derived from steer data for cows. These issues allow the equation for determining the maintenance energy requirement of cows to be called in to question independently of whether the impact of environment on maintenance energy requirements is estimated correctly.

Both of the two previous mentioned possible explanations for inaccurate ADG prediction affect predicted ADG only through their impact on maintenance energy requirements and subsequently the energy available for gain. There is also the potential that the equations predicting ADG from intake energy surplus to maintenance requirements could be flawed. With feedlot cattle, there ADG prediction equations take into account changes in the composition of gain that occur as cattle fatten by increasing the energy content of gain with increasing body weight and more rapid rates of gain to reflect the increased fat content of gain occurring in these situations. The equations predicting ADG of mature cows do not reflect any changes in body composition or the composition of gain. All mature cows are expected to gain 1 kg of SBW for every 5.82 Mcal of NE_m available in excess of maintenance, pregnancy, and lactation requirements. This expectation has obvious potential to contribute to inaccurate prediction of ADG with wintering beef cows.

With the previous feedlot based evaluations of ADG predictions (Block et al. 2001, 2006) the relatively large observed and predicted ADG provided limited ability to narrow down possible causes of inaccurate ADG. However, with the current evaluation using wintering cows with substantially lower ADG than growing cattle, it was possible to specifically identify a problem with the prediction maintenance requirements when using actual environmental conditions. This stems from the observation that predicted ADG means were often negative whereas observed ADG means were positive (Tables 7 and 8). While this does not exclude a possible issue with the accuracy of the equation relating surplus energy intake to ADG, the only way in which cows can demonstrate positive ADG while being predicted to have negative ADG is for there to be an error in the prediction of amount of feed required for maintenance.

Re-evaluation of ADG predictions under the assumption of thermal neutral conditions has the effect of removing the impact of suspect environmental effect equations. This has the potential to improve the precision and accuracy of ADG predictions, although improved predictions would still not necessarily serve as proof of inadequate environmental effect estimation.

When all three years of 2nd trimester ADG data from the Saskatoon data sets were evaluated collectively under the assumption of thermal neutral conditions (Table 9), there was a relationship ($P<0.01$) between observed and predicted ADG with predicted ADG explaining 54% of the variation in ADG with a $s_{y.x}$ of 0.13 kg. This relationship did differ ($P<0.05$) from the isopleth indicating inaccurate prediction of ADG with 30% of the inaccuracy due to bias, 53% due to slope, and 17% due to residual error components. Gains were generally over predicted, although to a lesser degree than the under prediction that occurred when using actual environmental conditions. The CCC of 0.51 suggests moderate agreement between observed and predicted ADG, although the TDI_{90} of 0.50 kg and expectation that only 57% of the pens of cows would have predicted and observed ADG agree within 0.25 kg do suggest that practical application of these ADG predictions would be limited.

With all of the 3rd trimester ADG predictions from the Saskatoon data sets made using actual environmental conditions being positive, this set of data does not provide any additional support to the idea that part of the error in ADG predictions can be specifically attributed to errors in maintenance energy requirement determinations. Additionally, with ADG predicted using actual environmental conditions being either very similar to observed ADG or over predicted removing the effect of cold environments on the prediction of ADG is not expected to result in improved ADG prediction accuracy or precision. This was case for all three years when

evaluated individually or collectively (Table 9) with no relationship (P=0.60 to 0.87) between observed and predicted ADG with predicted ADG explaining <2% of variation in observed ADG in all cases and $s_{y \cdot x}$ of 0.12 to 0.17 kg. Inaccurate prediction was identified based on a relationship (P<0.01 to 0.01) between residual and predicted ADG with predicted ADG explaining 42 to 77% of the variation in ADG prediction error. Gain was generally over predicted in all cases with CCC of -0.01 to 0.02 indicating no relationship between observed and predicted ADG while relative bias square values of 1.25 to 11.79 were all >1 and invalidated the TDI_{90} and CP statistics.

For the Lacombe data sets, evaluation of all three years of ADG predictions under the assumption of thermal neutral conditions (Table 10) found observed and predicted ADG to be related (P=0.01) with 6% of the variation in observed ADG explained with a $s_{y \cdot x}$ of 0.22 kg. This relationship differed (P<0.01) from the isopleth indicating in accurate prediction of ADG with 86% of the inaccuracy due to slope and 14% of the inaccuracy due to residual error components. Gains were generally under predicted at when predictions were low, and over predicted when predictions were high. The CCC of 0.17 indicates low agreement between observed and predicted ADG and is supported by the large TDI_{90} of 0.97 kg and low CP of 32%.

There was no relationship (P=0.30) between observed and predicted ADG for the Melfort data set (Table 10) with only 3% of the variation in observed ADG being explained by predicted ADG with a $s_{y \cdot x}$ of 0.23 kg. There was a relationship (P<0.01) between residual and predicted ADG indicating inaccurate prediction with 46% of the variation in the prediction error being explained by the prediction. Again, gains were generally under predicted at when predictions were low, and over predicted when predictions were high. The CCC of 0.16 indicates low

agreement between observed and predicted ADG and is supported by the large TDI_{90} of 0.51 kg and low CP of 57%.

When all ADG data were evaluated collectively under the assumption of thermal neutral conditions (Table 10), there was a relationship ($P<0.01$) between observed and predicted ADG that differed ($P<0.01$) from the isopleth indicating inaccurate prediction of ADG. Only 4% of the variation in observed ADG was explained by predicted ADG with a $s_{y.x}$ of 0.23 kg. Of the inaccuracy that existed, 4% was attributed to bias, 75% to slope, and 21% to residual error components. The CCC remained low at 0.16 indicating poor agreement between observed and predicted ADG, and was supported by the large TDI_{90} of 0.83 kg and low CP of 38%. On average, ADG predicted under the assumption of thermal neutral conditions was closer to observed ADG than ADG predicted using actual environmental conditions although gains were generally under predicted at when predictions were low, and over predicted when predictions were high.

Although the assumption of thermal neutral conditions for the winter feeding trials often resulted in predictions of ADG that were closer to observed ADF, they still lacked accuracy and precision. In all many cases where ADG was under predicted when using actual environmental conditions, ADG became over predicted when thermal neutral conditions were assumed. This suggests that the cows were affected by environmental conditions, but not a severely as suggested by the model equations. Unfortunately from a model evaluation viewpoint, when thermal neutral conditions were assumed almost all observed and predict ADG means were positive. Had any of the prediction means remained negative while the cows demonstrated positive gains, it would have been clear evidence that the base maintenance energy requirement equations were inaccurate. As this did not occur, no firm conclusions can yet be made regarding

where the inaccuracy in maintenance energy requirements lies. However, the frequent observation that gains were generally under predicted at when predictions were low, and over predicted when predictions were high suggest that the model equations are responding to factors that the cattle themselves are either insensitive to, or are compensating for. This contrasts with the DMI prediction observations where the cattle appeared to be responding to factors that the models was not taking into account.

Conclusions

This evaluation of NRC (1996, 2000) model energy requirement and DMI equation for wintering beef cows in western Canada found the equations to lack accuracy and precision in prediction of intake and gain. This situation was not resolved by removing the impact of the environment based adjusters by assuming thermal neutral conditions and calls into question the practical applicability of the equations for use in beef cow feeding management. There are several possible areas where improvements could be made in the predictions of intake and gain of beef cows. These include development of equations that are more reflective of the limitations to DMI by cows (ie. fill effects instead of chemo-osmotic effects), maintenance energy requirement equations that are specific to cows instead of using equations adapted from feedlot cattle, and gain prediction equations that reflect that the composition of gain changes with cow condition. These are all issues that have not been addressed in the current energy requirement and intake equations. The inability of the current equations to accurately and precisely predict intake and gain of wintering beef cows should not be viewed as a failure, but rather a success in providing direction for future research. Many of the issues discussed as limitations to the model equations exist only because there is a lack of quality data available for resolving them.

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Table 1. Summary of inputs (average ± SD) for prediction of DMI and ADG from the Saskatoon data sets.

	2002-2003		2003-2004		2004-2005	
	2nd trimester	3rd trimester	2nd trimester	3rd trimester	2nd trimester	3rd trimester
n[z]	15	15	15	15	15	15
DMI, kg d^{-1}	10.93 ± 0.44	12.70 ± 0.90	11.52 ± 0.78	13.63 ± 0.53	13.10 ± 1.03	12.74 ± 0.63
TDN, %	51.74 ± n/a	56.38 ± n/a	49.75 ± n/a	56.38 ± n/a	55.56 ± n/a	61.05 ± 0.97
Temperature, C						
Previous	-7.2 ± 0.3	-13.8 ± 2.2	-10.9 ± 0.1	-10.2 ± 1.5	1.0 ± 0.0	-15.5 ± 1.1
Current	-9.6 ± 1.4	-10.1 ± 2.6	-11.6 ± 1.3	-8.2 ± 1.1	-11.7 ± 0.5	-5.4 ± 1.8
Wind speed, km h^{-1}	5.0 ± n/a	5.0 ± n/a	5.0 ± n/a	5.0 ± n/a	5.0 ± n/a	5.0 ± n/a
Body condition score, 9-point	5.4 ± 0.2	5.4 ± 0.2	4.7 ± 0.3	5.1 ± 0.3	5.7 ± 0.5	5.7 ± 0.5
Days pregnant	158 ± 5	237 ± 5	164 ± 8	243 ± 4	152 ± 8	233 ± 5
Calf birth weight, kg	45.1 ± 1.7		44.3 ± 2.2		50.0 ± 3.1	
ADG, kg	0.13 ± 0.09	0.00 ± 0.12	0.07 ± 0.12	0.15 ± 0.14	0.39 ± 0.15	-0.12 ± 0.13

[z] Each replicate was a pen of six cows.

Table 2. Summary of inputs (average ± SD) for prediction of DMI and ADG from the Lacombe and Melfort data sets.

	Lacombe 2003-2004	Lacombe 2004-2005	Lacombe 2005-2006	Melfort 1981-1985
n	37	40	38	40
DMI, kg d^{-1}	14.46 ± 2.39	13.46 ± 1.95	11.24 ± 2.46	9.69 ± 1.06
TDN, %	53.84 ± n/a	53.78 ± n/a	48.93 ± n/a	54.52 ± 2.12
Temperature, °C				
Previous	-9.6 ± n/a	-5.9 ± 0.7	-2.5 ± n/a	-5.5 ± 1.9
Current	-11.5 ± n/a	-6.7 ± 0.5	-3.7 ± n/a	-13.9 ± 1.3
Wind speed, km h^{-1}	3.6 ± n/a	5.5 ± 0.15	6.2 ± n/a	5.0 ± n/a
Body condition score, 9-point	5.4 ± 1.1	5.7 ± 1.1	5.6 ± 0.7	4.8 ± 1.6
Days pregnant	193 ± 10	170 ± 10	167 ± 11	185 ± 24
Calf birth weight, kg	44.1 ± 6.9	49.0 ± 7.6	45.5 ± 5.7	42.4 ± 2.2
ADG, kg	0.33 ± 0.24	0.31 ± 0.21	0.23 ± 0.23	0.10 ± 0.23

[z] Each of the Lacombe replicates was an individual cow and each of the Melfort replicates was a pen of 25 cows.

Table 3. Accuracy and precision evaluation results for the Saskatoon data sets predictions of DMI made using actual environmental conditions.

	U of S 2002-2003 2nd trimester	U of S 2003-2004 2nd trimester	U of S 2004-2005 2nd trimester	U of S 2002-2003 3rd trimester	U of S 2003-2004 3rd trimester	U of S 2004-2005 3rd trimester	U of S All 2nd trimester	U of S All 3rd trimester
n	15	15	15	15	15	15	45	45
Regression of observed vs. predicted								
Intercept ± SE[z]	3.83 ± 10.08	-2.46 ± 26.05	-23.57 ± 10.09	-11.10 ± 17.92	19.52 ± 15.85	2.18 ± 4.04	-16.06 ± 2.88	5.59 ± 4.74
Slope ± SE[z]	0.55 ± 0.78	1.07 ± 1.99	2.63 ± 0.73	1.78 ± 1.34	-0.44 ± 1.17	0.77 ± 0.29	2.10 ± 0.22	0.55 ± 0.35
P-value for regression[y]	0.49	0.60	<0.01	0.21	0.72	0.02	<0.01	0.12
R^2	0.04	0.02	0.50	0.12	0.01	0.35	0.69	0.05
$s_{y.x}$, kg d^{-1}	0.45	0.80	0.75	0.88	0.55	0.53	0.68	0.80
P-value for isopleth[x]	<0.01	<0.01	<0.01	0.04	0.34	<0.01	<0.01	<0.01
Bias, kg d^{-1}	2.01	1.57	0.82	0.64	0.13	1.02	1.47	0.51
Mean square error of prediction	4.50	3.23	1.46	1.17	0.33	1.39	2.92	0.92
Bias, %	96	80	48	35	6	79	74	28
Slope, %	0	0	14	2	9	1	10	3
Correlation, %	4	20	38	63	85	20	16	69
Regression of residual vs. predicted								
Intercept ± SE[z]	-3.83 ± 10.08	2.46 ± 26.05	23.57 ± 10.09	11.10 ± 17.92	-19.52 ± 15.85	-2.18 ± 4.04	16.06 ± 2.88	-5.59 ± 4.74
Slope ± SE[z]	0.45 ± 0.78	-0.07 ± 1.99	-1.63 ± 0.73	-0.78 ± 1.34	1.44 ± 1.17	0.23 ± 0.29	-1.10 ± 0.22	0.45 ± 0.35
P-value for regression[y]	0.57	0.97	0.04	0.57	0.24	0.44	<0.00	0.21
R^2	0.03	<0.01	0.28	0.03	0.10	0.05	0.37	0.04
$s_{y.x}$, kg d^{-1}	0.45	0.80	0.75	0.88	0.55	0.53	0.68	0.80
Means comparison								
Observed, kg d^{-1}	10.93	11.52	13.10	12.70	13.63	12.74	11.85	13.02
Predicted, kg d^{-1}	12.93	13.09	13.92	13.34	13.50	13.76	13.31	13.53
SE[z]	0.08	0.14	0.20	0.17	0.10	0.14	0.14	0.09
P-value	<0.01	<0.01	0.01	0.01	0.36	<0.01	<0.01	<0.01
Concordance correlation coefficient	0.01	0.01	0.22	0.09	-0.04	0.20	0.24	0.12
Precision coefficient	0.19	0.15	0.71	0.35	-0.10	0.59	0.83	0.23
Accuracy coefficient	0.03	0.05	0.31	0.25	0.42	0.35	0.30	0.54
Total deviation index, kg d^{-1}	3.49	2.96	1.99	1.78	0.94	1.94	2.81	1.57
Coverage probability, %	2	24	55	61	90	49	29	69
Relative bias square[w]	18.18	3.59	0.79	0.47	0.05	3.30	2.83	0.38

[z] Standard error of the intercept, slope, or least square means.

[y] Significance of the regression relationship between observed or residual and predicted values.

[x] Significance of the test for equality between the fitted regression equation and the isopleth.

[w] Relative bias square must be ≤1 for the total deviation index and coverage probability statistics to be valid.

Table 4. Accuracy and precision evaluation results for the Lacombe, Melfort, and All data set predictions of DMI made using actual environmental conditions.

	Lacombe 2003-2004	Lacombe 2004-2005	Lacombe 2005-2006	Lacombe All	Melfort 1981-1985	All Data Sets
n	37	40	38	115	40	245
Regression of observed vs. predicted						
Intercept ± SE[z]	4.40 ± 5.01	7.11 ± 3.62	3.84 ± 6.04	0.91 ± 2.24	9.47 ± 1.86	1.31 ± 1.26
Slope ± SE[z]	0.80 ± 0.40	0.49 ± 0.28	0.66 ± 0.54	0.99 ± 0.18	0.02 ± 0.17	0.88 ± 0.10
P-value for regression[y]	0.05	0.09	0.23	<0.01	0.91	<0.01
R^2	0.10	0.08	0.04	0.21	<0.01	0.24
$s_{y.x}$, kg d^{-1}	2.29	1.90	2.44	2.34	1.07	2.01
P-value for isopleth[x]	<0.01	0.07	0.82	<0.01	<0.01	0.12
Bias, kg d^{-1}	1.82	0.46	<0.01	0.75	1.25	0.22
Mean square error of prediction	8.57	4.06	5.87	6.00	3.67	4.08
Bias, %	40	5	0	9	43	1
Slope, %	0	8	1	0	27	1
Correlation, %	60	87	99	91	31	98
Regression of residual vs. predicted						
Intercept ± SE[z]	-4.40 ± 5.01	-7.11 ± 3.62	-3.84 ± 6.04	-0.91 ± 2.24	-9.47 ± 1.86	-1.31 ± 1.26
Slope ± SE[z]	0.20 ± 0.40	0.51 ± 0.28	0.34 ± 0.54	0.01 ± 0.18	0.98 ± 0.17	0.12 ± 0.10
P-value for regression[y]	0.61	0.07	0.53	0.94	<0.01	0.22
R^2	0.01	0.08	0.01	<0.01	0.47	0.01
$s_{y.x}$, kg d^{-1}	2.29	1.90	2.44	2.34	1.07	2.01
Means comparison						
Observed, kg d^{-1}	14.46	13.46	11.24	13.05	9.69	12.27
Predicted, kg d^{-1}	12.64	13.00	11.24	12.30	10.93	12.49
SE[z]	0.30	0.25	0.29	0.19	0.16	0.12
P-value	<0.01	0.19	0.99	0.01	<0.01	0.20
Concordance correlation coefficient	0.15	0.23	0.11	0.33	0.01	0.42
Precision coefficient	0.32	0.28	0.20	0.46	0.02	0.49
Accuracy coefficient	0.46	0.82	0.56	0.71	0.57	0.85
Total deviation index, kg d^{-1}	4.81	3.31	3.98	4.03	3.15	3.32
Coverage probability, %	25	37	31	31	37	38
Relative bias square[w]	0.61	0.05	<0.01	0.10	0.71	0.01

[z] Standard error of the intercept, slope, or least square means.

[y] Significance of the regression relationship between observed or residual and predicted values.

[x] Significance of the test for equality between the fitted regression equation and the isopleth.

[w] Relative bias square must be ≤1 for the total deviation index and coverage probability statistics to be valid.

Table 5. Accuracy and precision evaluation results for the Saskatoon data sets predictions of DMI made assuming thermal neutral conditions.

	U of S 2002-2003 2nd trimester	U of S 2003-2004 2nd trimester	U of S 2004-2005 2nd trimester	U of S 2002-2003 3rd trimester	U of S 2003-2004 3rd trimester	U of S 2004-2005 3rd trimester	U of S All 2nd trimester	U of S All 3rd trimester
n	15	15	15	15	15	15	45	45
Regression of observed vs. predicted								
Intercept ± SE[z]	12.90 ± 1.73	-2.46 ± 26.05	-23.59 ± 9.95	7.07 ± 3.17	19.52 ± 15.85	7.21 ± 4.88	3.15 ± 3.66	13.20 ± 2.17
Slope ± SE[z]	-0.17 ± 0.15	1.24 ± 2.31	3.06 ± 0.83	0.47 ± 0.26	-0.51 ± 1.36	0.44 ± 0.38	0.75 ± 0.31	-0.01 ± 0.18
P-value for regression[y]	0.27	0.60	<0.01	0.10	0.72	0.28	0.02	0.94
R^2	0.09	0.02	0.51	0.20	0.01	0.09	0.12	<0.01
$s_{y.x}$, kg d^{-1}	0.43	0.80	0.75	0.84	0.55	0.62	1.14	0.82
P-value for isopleth[x]	<0.01	0.53	<0.01	0.01	<0.01	0.35	0.34	<0.01
Bias, kg d^{-1}	0.70	0.24	1.10	0.71	1.99	0.06	0.21	0.92
Mean square error of prediction	1.52	0.65	2.06	1.40	4.55	0.42	1.35	2.03
Bias, %	33	8	61	37	92	1	3	43
Slope, %	56	0	13	15	1	14	1	25
Correlation, %	12	92	26	48	7	85	96	33
Regression of residual vs. predicted								
Intercept ± SE[z]	-12.90 ± 1.73	2.46 ± 26.05	23.59 ± 9.95	-7.07 ± 3.17	-19.52 ± 15.85	-7.21 ± 4.88	-3.15 ± 3.66	-13.20 ± 2.17
Slope ± SE[z]	1.17 ± 0.15	-0.24 ± 2.31	-2.06 ± 0.83	0.53 ± 0.26	1.51 ± 1.36	0.56 ± 0.38	0.25 ± 0.31	1.01 ± 0.18
P-value for regression[y]	<0.01	0.92	0.03	0.07	0.29	0.17	0.43	<0.01
R^2	0.83	<0.01	0.32	0.24	0.09	0.14	0.01	0.43
$s_{y.x}$, kg d^{-1}	0.43	0.80	0.75	0.84	0.55	0.62	1.14	0.82
Means comparison								
Observed, kg d^{-1}	10.93	11.52	13.10	12.70	13.63	12.74	11.85	13.02
Predicted, kg d^{-1}	11.62	11.29	12.00	11.99	11.64	12.67	11.64	12.10
SE[z]	0.16	0.14	0.19	0.23	0.10	0.14	0.14	0.11
P-value	0.01	0.25	<0.01	0.03	<0.01	0.75	0.28	<0.01
Concordance correlation coefficient	-0.16	0.03	0.15	0.33	-0.01	0.28	0.25	-0.01
Precision coefficient	-0.30	0.15	0.72	0.44	-0.10	0.30	0.34	-0.01
Accuracy coefficient	0.52	0.21	0.21	0.74	0.02	0.93	0.74	0.56
Total deviation index, kg d^{-1}	2.03	1.32	2.36	1.95	3.51	1.07	1.91	2.34
Coverage probability, %	55	75	45	57	5	85	60	49
Relative bias square[w]	0.41	0.08	1.35	0.51	11.24	0.01	0.03	0.70

[z] Standard error of the intercept, slope, or least square means.

[y] Significance of the regression relationship between observed or residual and predicted values.

[x] Significance of the test for equality between the fitted regression equation and the isopleth.

[w] Relative bias square must be ≤1 for the total deviation index and coverage probability statistics to be valid.

Table 6. Accuracy and precision evaluation results for the Lacombe, Melfort, and All data set predictions of DMI made assuming thermal neutral conditions.

	Lacombe 2003-2004	Lacombe 2004-2005	Lacombe 2005-2006	Lacombe All	Melfort 1981-1985	All Data Sets
n	37	40	38	115	40	245
Regression of observed vs. predicted						
Intercept ± SE[z]	4.39 ± 5.01	6.61 ± 3.83	3.89 ± 6.04	3.04 ± 3.08	9.46 ± 1.86	2.94 ± 1.31
Slope ± SE[z]	0.92 ± 0.46	0.61 ± 0.34	0.69 ± 0.56	0.91 ± 0.28	0.02 ± 0.20	0.85 ± 0.12
P-value for regression[y]	0.05	0.08	0.23	<0.01	0.90	<0.01
R^2	0.10	0.08	0.04	0.09	<0.01	0.18
$s_{y,x}$, kg d^{-1}	2.29	1.90	2.44	2.52	1.07	2.09
P-value for isopleth[x]	<0.01	<0.01	0.36	<0.01	<0.01	<0.01
Bias, kg d^{-1}	3.57	2.23	0.53	2.10	0.26	1.24
Mean square error of prediction	18.18	8.76	6.14	10.73	1.89	5.92
Bias, %	71	58	5	41	4	26
Slope, %	0	1	1	0	38	1
Correlation, %	29	41	94	59	58	73
Regression of residual vs. predicted						
Intercept ± SE[z]	-4.39 ± 5.01	-6.61 ± 3.83	-3.89 ± 6.04	-3.04 ± 3.08	-9.46 ± 1.86	-2.94 ± 1.31
Slope ± SE[z]	0.08 ± 0.46	0.39 ± 0.34	0.31 ± 0.56	0.09 ± 0.28	0.98 ± 0.20	0.15 ± 0.12
P-value for regression[y]	0.87	0.26	0.58	0.76	<0.01	0.19
R^2	<0.01	0.03	0.01	<0.01	0.39	0.01
$s_{y,x}$, kg d^{-1}	2.29	1.90	2.44	2.52	1.07	2.09
Means comparison						
Observed, kg d^{-1}	14.46	13.46	11.24	13.05	9.69	12.27
Predicted, kg d^{-1}	10.90	11.23	10.71	10.95	9.42	11.04
SE[z]	0.29	0.24	0.29	0.18	0.15	0.12
P-value	<0.01	<0.01	0.20	<0.01	0.23	<0.01
Concordance correlation coefficient	0.07	0.10	0.10	0.11	0.02	0.27
Precision coefficient	0.32	0.28	0.20	0.29	0.02	0.42
Accuracy coefficient	0.20	0.36	0.51	0.37	0.95	0.64
Total deviation index, kg d^{-1}	7.01	4.87	4.08	5.39	2.26	4.00
Coverage probability, %	11	21	31	22	52	31
Relative bias square[w]	2.35	1.30	0.05	0.69	0.04	0.35

[z] Standard error of the intercept, slope, or least square means.

[y] Significance of the regression relationship between observed or residual and predicted values.

[x] Significance of the test for equality between the fitted regression equation and the isopleth.

[w] Relative bias square must be ≤1 for the total deviation index and coverage probability statistics to be valid.

Table 7. Accuracy and precision evaluation results for the Saskatoon data sets predictions of ADG made using actual environmental conditions.

	U of S 2002-2003 2nd trimester	U of S 2003-2004 2nd trimester	U of S 2004-2005 2nd trimester	U of S 2002-2003 3rd trimester	U of S 2003-2004 3rd trimester	U of S 2004-2005 3rd trimester	U of S All 2nd trimester	U of S All 3rd trimester
n	15	15	15	15	15	15	45	45
Regression of observed vs. predicted								
Intercept ± SE[z]	0.19 ± 0.06	0.14 ± 0.06	0.13 ± 0.07	0.04 ± 0.03	0.15 ± 0.05	-0.10 ± 0.04	0.21 ± 0.02	0.00 ± 0.03
Slope ± SE[z]	0.25 ± 0.23	0.22 ± 0.15	0.54 ± 0.15	0.36 ± 0.12	-0.02 ± 0.28	-0.19 ± 0.24	0.38 ± 0.04	0.17 ± 0.13
P-value for regression[y]	0.30	0.18	<0.01	0.01	0.96	0.44	<0.01	0.18
R^2	0.08	0.14	0.52	0.41	<0.01	0.05	0.69	0.04
$s_{y.x}$, kg d^{-1}	0.09	0.11	0.10	0.10	0.14	0.14	0.10	0.17
P-value for isopleth[x]	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01
Bias, kg d^{-1}	0.37	0.40	0.09	0.10	0.01	0.21	0.23	0.03
Mean square error of prediction	0.16	0.21	0.03	0.04	0.04	0.10	0.13	0.06
Bias, %	91	82	30	26	0	48	42	2
Slope, %	4	12	30	51	50	37	50	48
Correlation, %	5	6	39	23	50	19	8	50
Regression of residual vs. predicted								
Intercept ± SE[z]	-0.19 ± 0.06	-0.14 ± 0.06	-0.13 ± 0.07	-0.04 ± 0.03	-0.15 ± 0.05	0.10 ± 0.04	-0.21 ± 0.02	0.00 ± 0.03
Slope ± SE[z]	0.75 ± 0.23	0.78 ± 0.15	0.46 ± 0.15	0.64 ± 0.12	1.02 ± 0.28	1.19 ± 0.24	0.62 ± 0.04	0.83 ± 0.13
P-value for regression[y]	0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
R^2	0.45	0.67	0.43	0.69	0.49	0.66	0.86	0.49
$s_{y.x}$, kg d^{-1}	0.09	0.11	0.10	0.10	0.14	0.14	0.10	0.17
Means comparison								
Observed, kg d^{-1}	0.13	0.07	0.39	0.00	0.15	-0.12	0.19	0.01
Predicted, kg d^{-1}	-0.24	-0.33	0.48	-0.10	0.14	0.09	-0.03	0.04
SE[z]	0.03	0.04	0.04	0.05	0.03	0.04	0.05	0.03
P-value	<0.01	<0.01	0.17	0.13	0.80	<0.01	<0.01	0.42
Concordance correlation coefficient	0.03	0.08	0.60	0.46	-0.01	-0.10	0.50	0.20
Precision coefficient	0.29	0.37	0.72	0.64	-0.01	-0.22	0.83	0.20
Accuracy coefficient	0.12	0.21	0.84	0.72	0.99	0.47	0.60	0.97
Total deviation index, kg d^{-1}	0.66	0.75	0.27	0.32	0.31	0.51	0.58	0.38
Coverage probability, %	18	23	86	77	78	54	49	70
Relative bias square[w]	7.95	3.82	0.37	0.31	0.00	0.73	0.67	0.02

[z] Standard error of the intercept, slope, or least square means.

[y] Significance of the regression relationship between observed or residual and predicted values.

[x] Significance of the test for equality between the fitted regression equation and the isopleth.

[w] Relative bias square must be ≤1 for the total deviation index and coverage probability statistics to be valid.

Table 8. Accuracy and precision evaluation results for the Lacombe, Melfort, and All data set predictions of ADG made using actual environmental conditions.

	Lacombe 2003-2004	Lacombe 2004-2005	Lacombe 2005-2006	Lacombe All	Melfort 1981-1985	All Data Sets
n	37	40	38	115	40	245
Regression of observed vs. predicted						
Intercept ± SE[z]	0.31 ± 0.04	0.31 ± 0.03	0.25 ± 0.07	0.31 ± 0.02	0.12 ± 0.06	0.21 ± 0.02
Slope ± SE[z]	0.10 ± 0.08	0.10 ± 0.07	0.03 ± 0.07	0.08 ± 0.03	0.03 ± 0.10	0.09 ± 0.03
P-value for regression[y]	0.23	0.15	0.72	0.01	0.77	<0.01
R^2	0.04	0.05	<0.01	0.06	<0.01	0.04
$s_{y.x}$, kg	0.24	0.21	0.23	0.22	0.23	0.23
P-value for isopleth[x]	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Bias, kg	0.18	0.33	1.00	0.51	0.60	0.37
Mean square error of prediction	0.29	0.33	1.35	0.64	0.54	0.42
Bias, %	12	34	76	40	68	33
Slope, %	69	53	20	52	22	54
Correlation, %	19	13	4	8	10	13
Regression of residual vs. predicted						
Intercept ± SE[z]	-0.31 ± 0.04	-0.31 ± 0.03	-0.25 ± 0.07	-0.31 ± 0.02	-0.12 ± 0.06	-0.21 ± 0.02
Slope ± SE[z]	0.90 ± 0.08	0.90 ± 0.07	0.97 ± 0.07	0.92 ± 0.03	0.97 ± 0.10	0.91 ± 0.03
P-value for regression[y]	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
R^2	0.78	0.81	0.84	0.87	0.70	0.81
$s_{y.x}$, kg	0.24	0.21	0.23	0.22	0.23	0.23
Means comparison						
Observed, kg	0.33	0.31	0.23	0.29	0.10	0.19
Predicted, kg	0.14	-0.02	-0.77	-0.22	-0.50	-0.18
SE[z]	0.06	0.06	0.07	0.04	0.05	0.03
P-value	0.05	<0.01	<0.01	<0.01	<0.01	<0.01
Concordance correlation coefficient	0.14	0.12	0.01	0.10	0.01	0.10
Precision coefficient	0.20	0.23	0.06	0.24	0.05	0.20
Accuracy coefficient	0.71	0.52	0.18	0.41	0.29	0.53
Total deviation index, kg	0.88	0.95	1.91	1.32	1.21	1.07
Coverage probability, %	35	32	8	23	18	29
Relative bias square[w]	0.12	0.48	2.96	0.65	2.04	0.49

[z] Standard error of the intercept, slope, or least square means.
[y] Significance of the regression relationship between observed or residual and predicted values.
[x] Significance of the test for equality between the fitted regression equation and the isopleth.
[w] Relative bias square must be <1 for the total deviation index and coverage probability statistics to be valid.

Table 9. Accuracy and precision evaluation results for the Saskatoon data sets predictions of ADG made assuming thermal neutral conditions.

	U of S 2002-2003 2nd trimester	U of S 2003-2004 2nd trimester	U of S 2004-2005 2nd trimester	U of S 2002-2003 3rd trimester	U of S 2003-2004 3rd trimester	U of S 2004-2005 3rd trimester	U of S All 2nd trimester	U of S All 3rd trimester
n	15	15	15	15	15	15	45	45
Regression of observed vs. predicted								
Intercept ± SE[z]	0.13 ± 0.03	-0.02 ± 0.05	-0.04 ± 0.11	-0.01 ± 0.06	0.12 ± 0.18	-0.02 ± 0.17	0.06 ± 0.03	0.04 ± 0.06
Slope ± SE[z]	-0.06 ± 0.11	0.40 ± 0.22	0.56 ± 0.14	0.03 ± 0.15	0.05 ± 0.31	-0.14 ± 0.26	0.38 ± 0.05	-0.05 ± 0.11
P-value for regression[y]	0.62	0.09	<0.01	0.85	0.87	0.60	<0.01	0.67
R^2	0.02	0.20	0.54	<0.01	<0.01	0.02	0.54	<0.01
$s_{y.x}$, kg d^{-1}	0.10	0.11	0.10	0.12	0.14	0.14	0.13	0.17
P-value for isopleth[x]	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Bias, kg d^{-1}	0.04	0.15	0.39	0.30	0.43	0.77	0.16	0.50
Mean square error of prediction	0.07	0.04	0.18	0.16	0.23	0.69	0.09	0.34
Bias, %	3	55	90	59	85	93	30	75
Slope, %	85	17	4	31	6	4	53	17
Correlation, %	12	28	6	10	9	3	17	8
Regression of residual vs. predicted								
Intercept ± SE[z]	-0.13 ± 0.03	0.02 ± 0.05	0.04 ± 0.11	0.01 ± 0.06	-0.12 ± 0.18	0.02 ± 0.17	-0.06 ± 0.03	-0.04 ± 0.06
Slope ± SE[z]	1.06 ± 0.11	0.60 ± 0.22	0.44 ± 0.14	0.97 ± 0.15	0.95 ± 0.31	1.14 ± 0.26	0.62 ± 0.05	1.05 ± 0.11
P-value for regression[y]	<0.01	0.02	0.01	<0.01	0.01	<0.01	<0.01	<0.01
R^2	0.87	0.36	0.43	0.77	0.42	0.60	0.76	0.67
$s_{y.x}$, kg d^{-1}	0.10	0.11	0.10	0.12	0.14	0.14	0.13	0.17
Means comparison								
Observed, kg d^{-1}	0.13	0.07	0.39	0.00	0.15	-0.12	0.19	0.01
Predicted, kg d^{-1}	0.09	0.21	0.78	0.30	0.58	0.66	0.36	0.51
SE[z]	0.05	0.03	0.04	0.05	0.03	0.04	0.04	0.03
P-value	0.52	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01
Concordance correlation coefficient	-0.10	0.26	0.19	0.02	0.01	-0.01	0.51	-0.01
Precision coefficient	-0.14	0.45	0.74	0.05	0.05	-0.15	0.73	-0.06
Accuracy coefficient	0.68	0.57	0.25	0.34	0.14	0.06	0.70	0.23
Total deviation index, kg d^{-1}	0.43	0.33	0.70	0.65	0.79	1.36	0.50	0.96
Coverage probability, %	61	77	16	41	17	1	57	19
Relative bias square[w]	0.02	1.07	7.62	1.25	5.06	11.79	0.40	2.84

[z] Standard error of the intercept, slope, or least square means.
[y] Significance of the regression relationship between observed or residual and predicted values.
[x] Significance of the test for equality between the fitted regression equation and the isopleth.
[w] Relative bias square must be ≤1 for the total deviation index and coverage probability statistics to be valid.

Table 10. Accuracy and precision evaluation results for the Lacombe, Melfort, and All data set predictions of ADG made assuming thermal neutral conditions.

	Lacombe 2003-2004	Lacombe 2004-2005	Lacombe 2005-2006	Lacombe All	Melfort 1981-1985	All Data Sets
n	37	40	38	115	40	245
Regression of observed vs. predicted						
Intercept ± SE[a]	0.25 ± 0.07	0.25 ± 0.05	0.24 ± 0.04	0.26 ± 0.02	0.10 ± 0.04	0.16 ± 0.02
Slope ± SE[a]	0.12 ± 0.09	0.14 ± 0.08	0.03 ± 0.08	0.09 ± 0.03	0.16 ± 0.15	0.09 ± 0.03
P-value for regression[b]	0.19	0.09	0.70	0.01	0.30	<0.01
R^2	0.05	0.07	<0.01	0.06	0.03	0.04
$s_{y.x}$, kg	0.24	0.21	0.23	0.22	0.23	0.23
P-value for isopleth[c]	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Bias, kg	0.33	0.15	0.53	0.02	0.07	0.10
Mean square error of prediction	0.33	0.19	0.56	0.35	0.10	0.26
Bias, %	34	12	50	0	5	4
Slope, %	49	66	41	86	43	75
Correlation, %	17	23	9	14	52	21
Regression of residual vs. predicted						
Intercept ± SE[a]	-0.25 ± 0.07	-0.25 ± 0.05	-0.24 ± 0.04	-0.26 ± 0.02	-0.10 ± 0.04	-0.16 ± 0.02
Slope ± SE[a]	0.88 ± 0.09	0.86 ± 0.08	0.97 ± 0.08	0.91 ± 0.03	0.84 ± 0.15	0.91 ± 0.03
P-value for regression[b]	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
R^2	0.75	0.74	0.81	0.86	0.46	0.78
$s_{y.x}$, kg	0.24	0.21	0.23	0.22	0.23	0.23
Means comparison						
Observed, kg	0.33	0.31	0.23	0.29	0.10	0.19
Predicted, kg	0.66	0.46	-0.30	0.27	0.03	0.29
SE[a]	0.06	0.05	0.06	0.04	0.04	0.02
P-value	<0.01	<0.01	<0.01	0.78	0.20	<0.01
Concordance correlation coefficient	0.13	0.20	0.02	0.17	0.16	0.14
Precision coefficient	0.22	0.27	0.06	0.25	0.79	0.19
Accuracy coefficient	0.58	0.74	0.38	0.66	0.96	0.76
Total deviation index, kg	0.94	0.71	1.23	0.97	0.51	0.83
Coverage probability, %	32	43	23	32	57	38
Relative bias square[d]	0.49	0.13	0.98	<0.01	0.05	0.04

[a] Standard error of the intercept, slope, or least square means.
[b] Significance of the regression relationship between observed or residual and predicted values.
[c] Significance of the test for equality between the fitted regression equation and the isopleth.
[d] Relative bias square must be ≤1 for the total deviation index and coverage probability statistics to be valid.

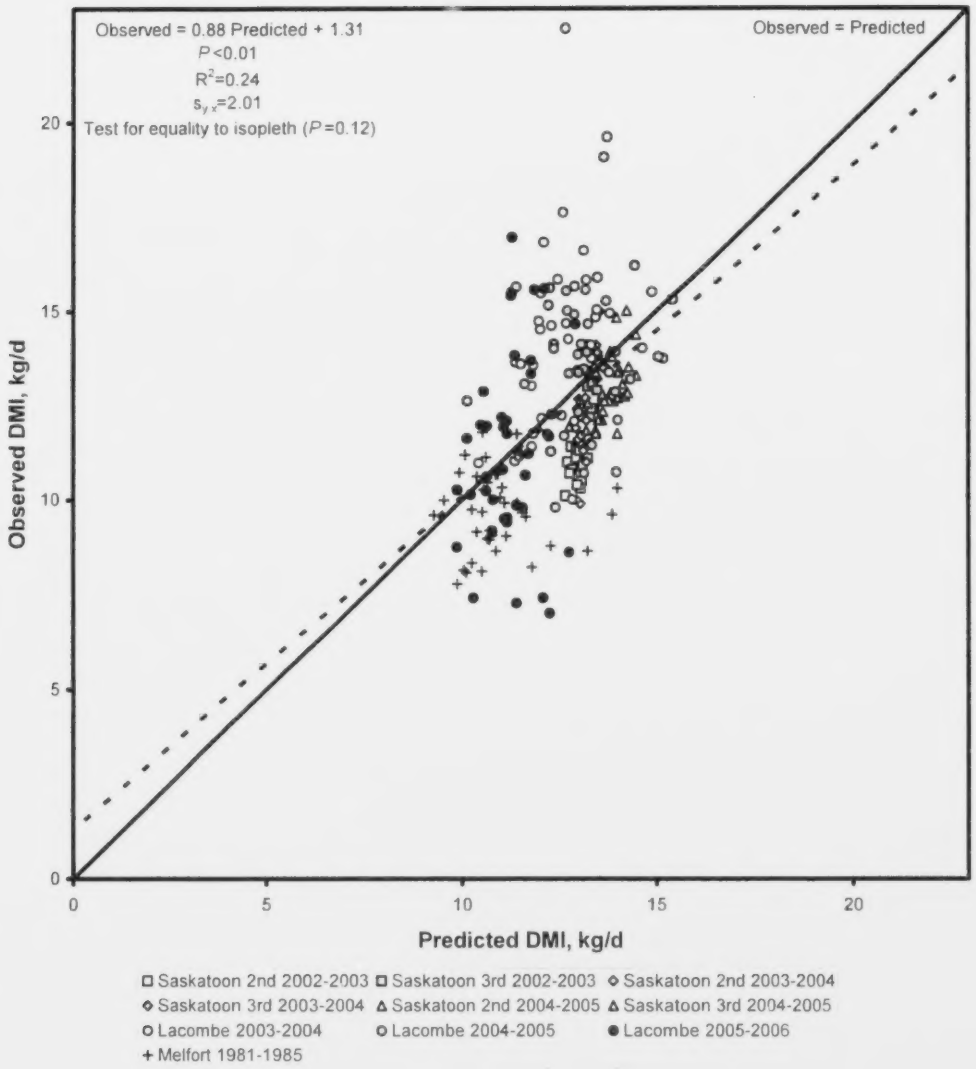

Figure 1. Evaluation of the NRC (1996, 2000) model DMI equation accuracy under the actual environmental conditions of all data sets. Each of the Saskatoon points represents one pen of six cows, the Lacombe points represent individual cows, and the Melfort points represent one pen of 30 cows. The solid line represents the isopleth (Y=X) line that would indicate accurate prediction. The dashed line represents the fitted regression equation for which the equation, fit statistics, and test for equality to the isopleth are shown.

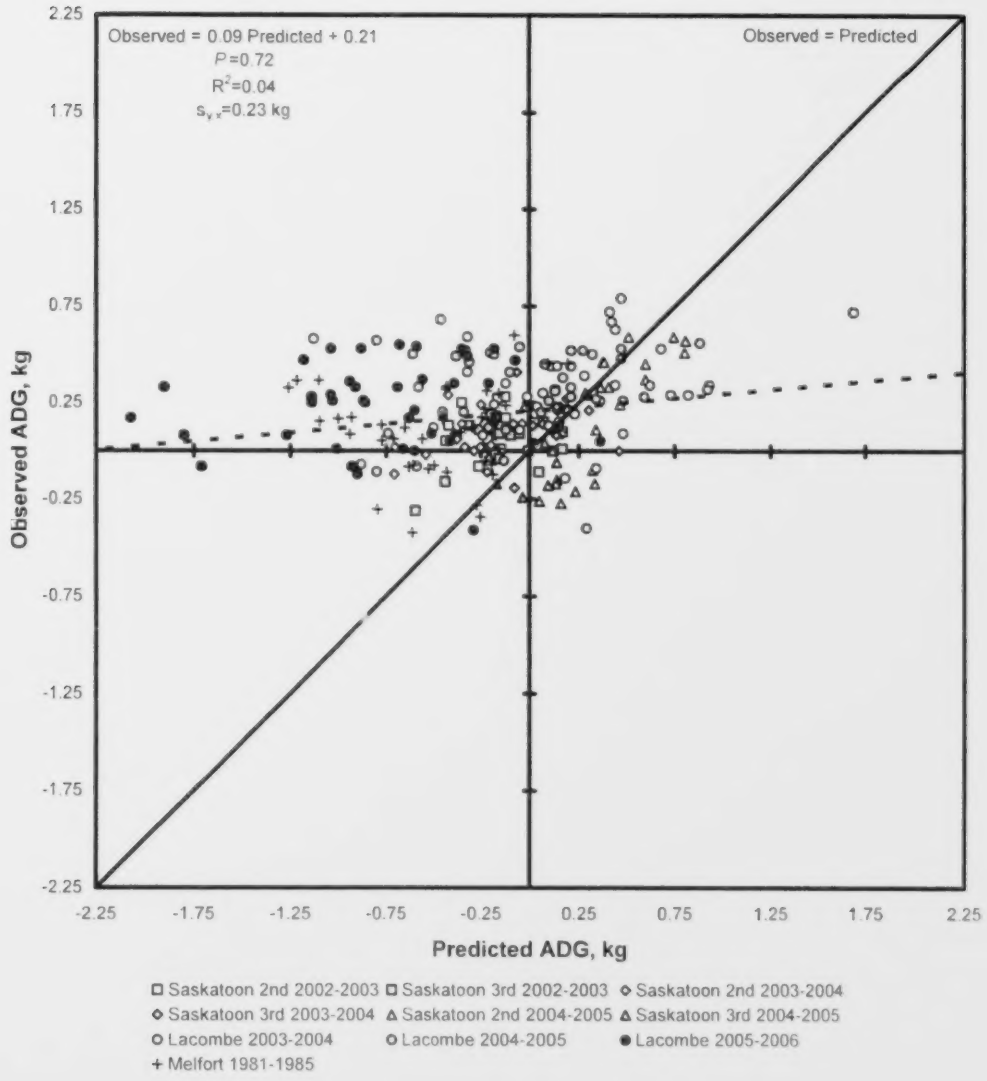

Figure 2. Evaluation of the NRC (1996, 2000) model energy requirement equations accuracy under the actual environmental conditions of all data sets. Each of the Saskatoon points represents one pen of six cows, the Lacombe points represent individual cows, and the Melfort points represent one pen of 30 cows. The solid line represents the isopleth (Y=X) line that would indicate accurate prediction. The dashed line represents the fitted regression equation for which the equation and fit statistics are shown.